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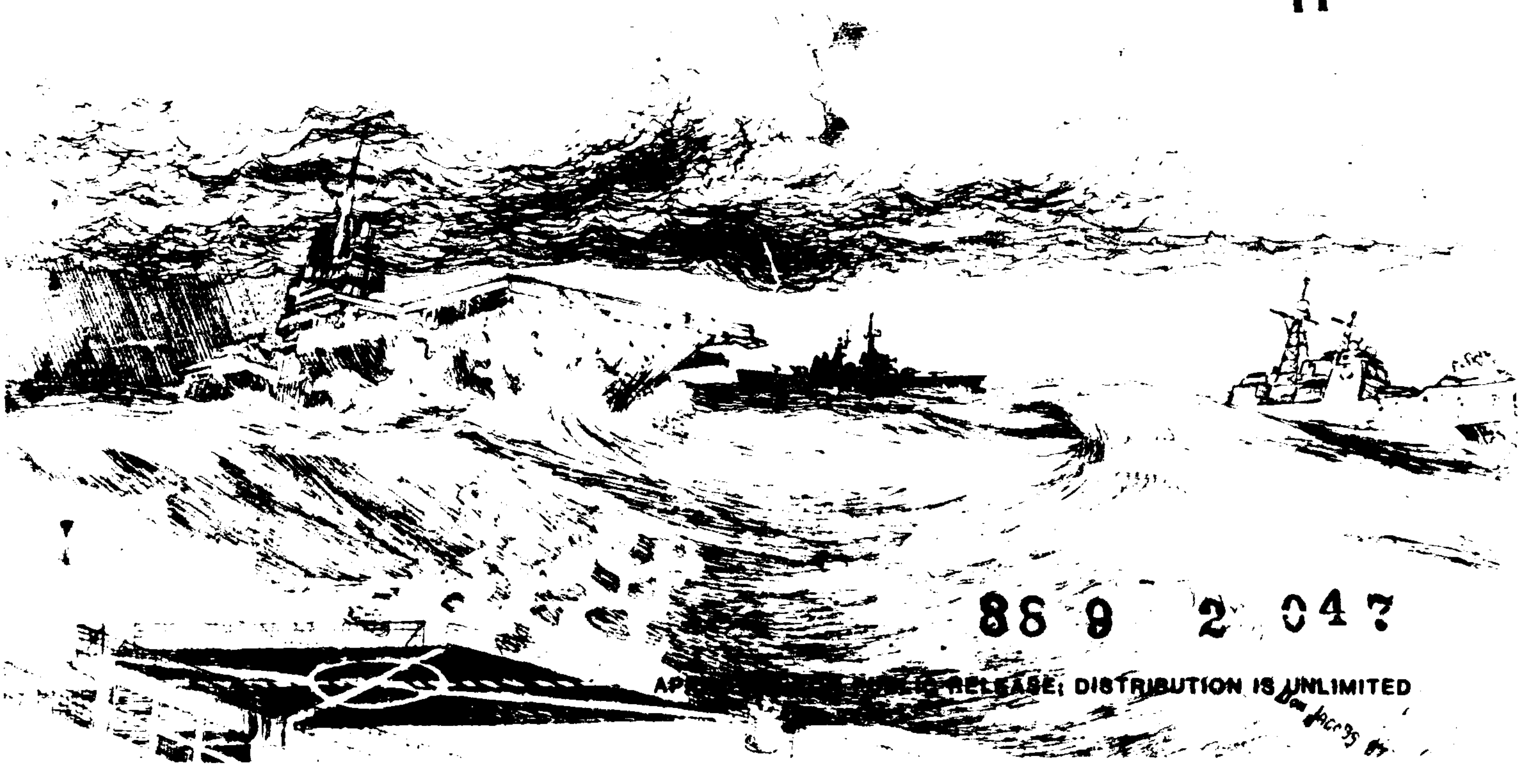
SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

19. POLLENSA BAY



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This handbook for the port of Pollensa Bay, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

W. L. SHUTT
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
16	BARCELONA, SPAIN
17	PALMA, SPAIN
18	IBIZA, SPAIN
19	POLLENSA BAY, SPAIN
20	LIVORNO, ITALY
21	LA SPEZIA, ITALY
22	VENICE, ITALY
23	TRIESTE, ITALY
24	CARTAGENA, SPAIN
25	VALENCIA, SPAIN
	SAN REMO, ITALY
	GENOA, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

Pollensa Bay is located on the island of Mallorca, approximately 100 n mi south-southeast of Barcelona and 165 n mi east of Valencia, Spain (Figure 2-1).

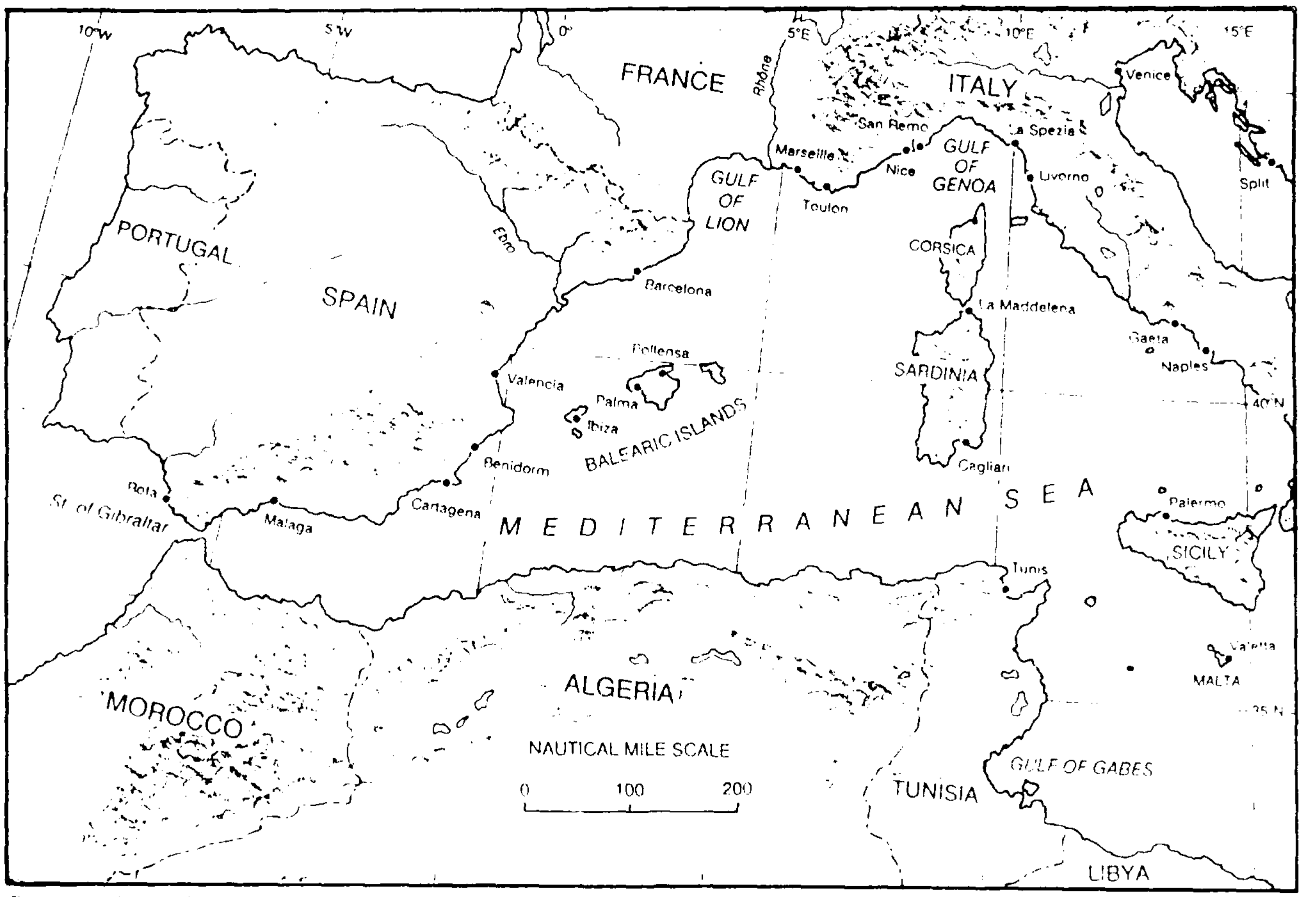

Figure 2-1 Western Mediterranean Sea

Pollensa Bay is situated on the northeast coast of Mallorca just south of Cabo de Formentor, the island's northernmost point (Figure 2-2). With approximate dimensions of 6.5 n mi by 2.75 n mi, the bay lies adjacent to and northwest of the larger Alcudia Bay.

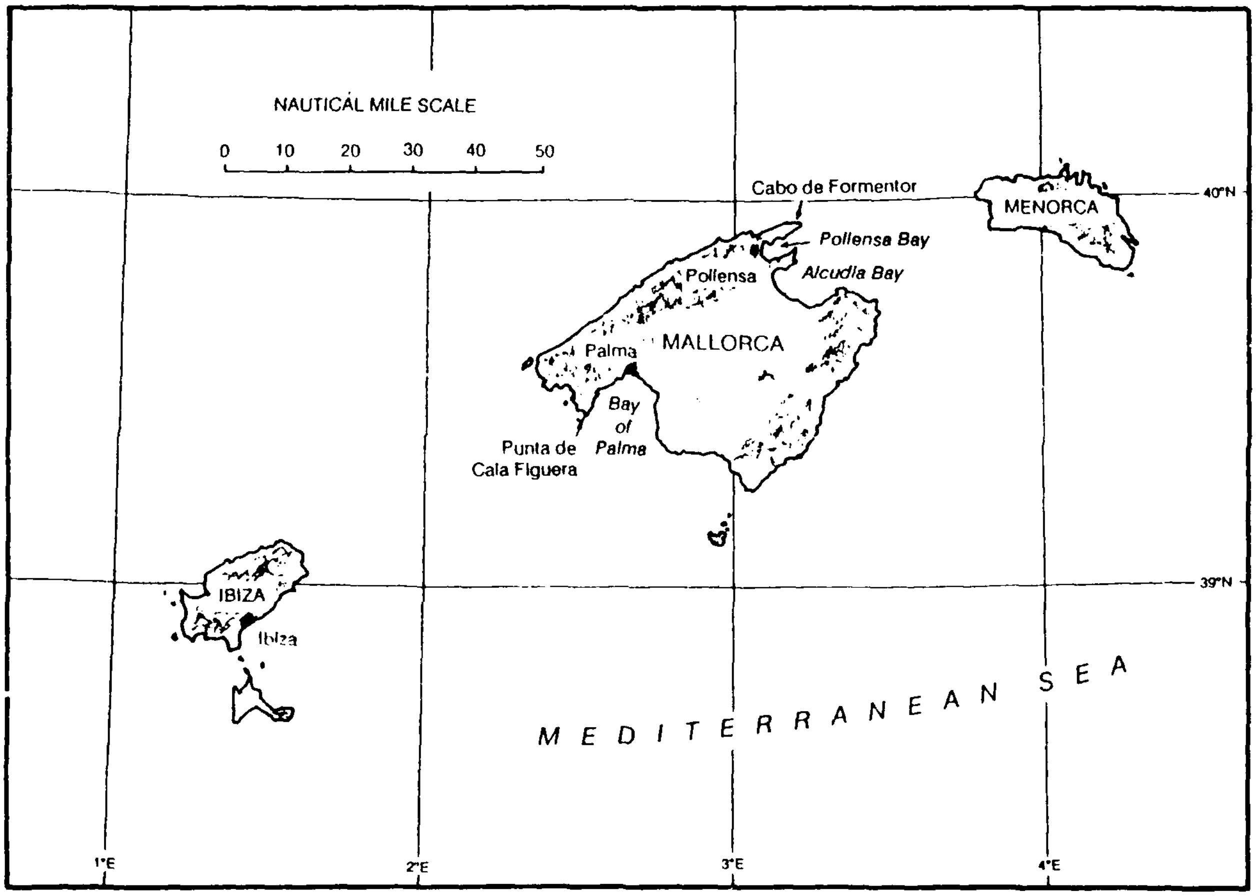

Figure 2-2. Balearic Islands.

The Port of Pollensa is situated in the northwest corner of Pollensa Bay, west of Punta de la Avanzada (Figure 2-3). The port is small, with unspecified facilities (FICEURLANT, 1987). Consequently, U.S. Navy ships anchor in the bay rather than mooring at the port. Most vessels anchor between Punta de la Avanzada and Punta de la Guarda, but aircraft carriers anchor southeast of and close to Isla de Formentor in order to gain the protection of Promoniorio del Formentor.

Pollensa Bay is bordered by land from the southeast clockwise through the northeast, leaving it exposed to winds and seas from the northeast through the southeast. It is vulnerable to the strong Mistral winds which originate in the Gulf of Lion. The bay is also subject to sudden squalls, with the area close to the high terrain on the northwestern side of the bay experiencing the worst conditions. Wave generation due to Mistral winds is limited by the small size of the bay. Southerly winds funnel to Pollensa Bay as they cross over the island east of its mountainous west coast, reaching the bay as southwesterly force 5 to 6 (17 to 27 kt). Holding is considered only fair on a bottom of fine to medium sand, mud, and weed; anchor dragging is a problem in strong winds. Strong southwesterly winds tend to cause ships to drag anchor northeastward toward deeper water, while the northwesterly Mistral winds cause dragging toward the southeast side of the bay.

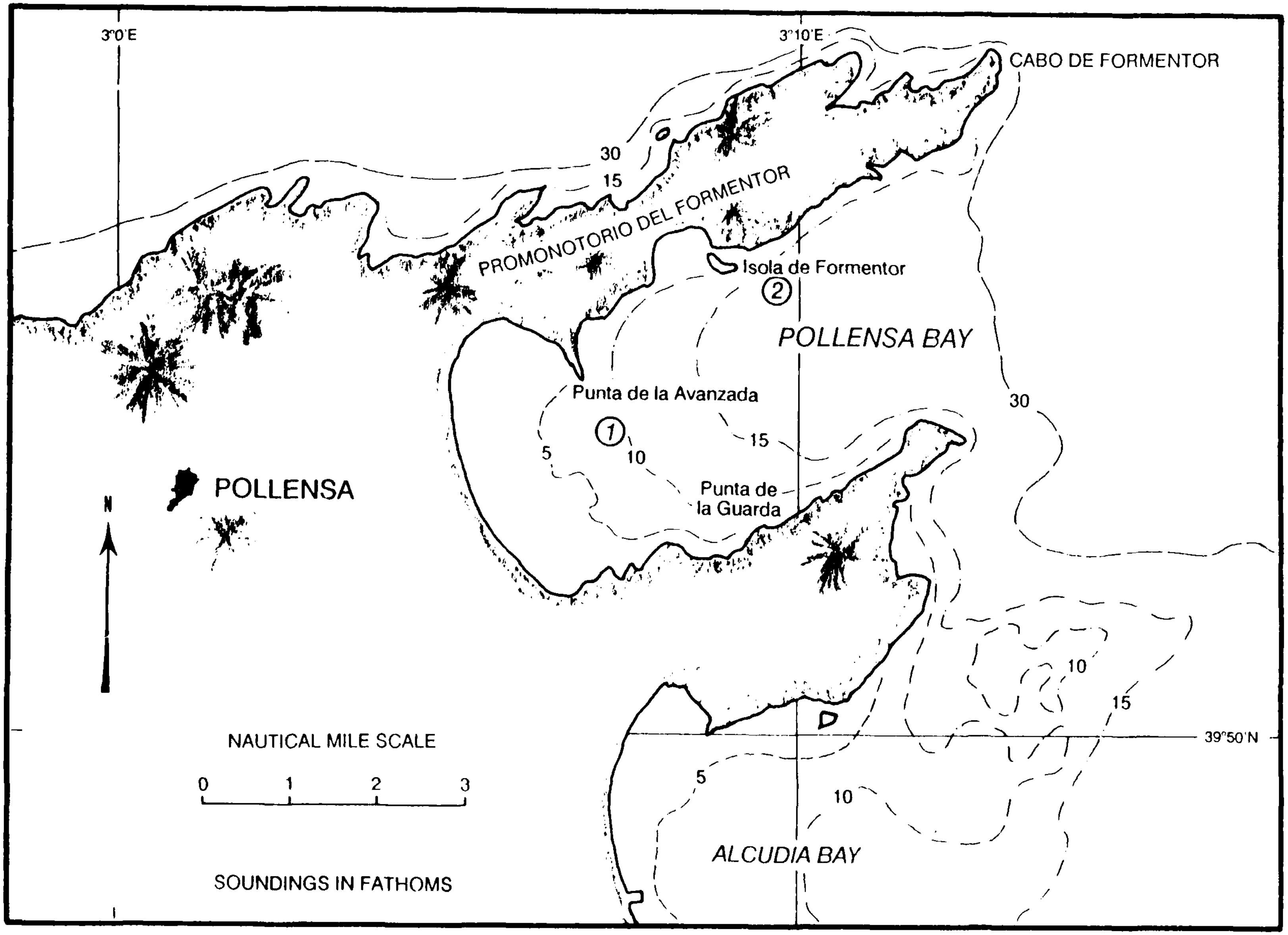

Figure 2-3. Port of Pollensa.

Currents within the bay are not specified, but a 1/2 kt current with a southeasterly set flows between Mallorca and Menorca Islands, with the current rate increasing when Mistral winds are blowing. Astronomical and wind tides are negligible. A barometric pressure tide exists ,however, with each 0.4 inches (10 mm) of pressure change, resulting in an inverse tidal change of 4 inches (10 cm).

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasive action scenarios are summarized in Table 2-1.

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Table 2-1. Summary of hazardous environmental co

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSE SITUAT
1. SW'ly wind - Caused by low pressure systems which pass through the Straits of Gibraltar and move NE along E coast of Spain. * Results when S'ly flow crosses island and funnels between peninsulas which form NW and SE sides of bay. * Often reaches force 5 to 6 (17-21 to 22-27 kt). * Lack of fetch restricts wave generation. * May be accompanied by low clouds and/or precipitation.	Advance warning * To be expected in advance of cold/occluded front which moves E across Iberian Peninsula. * May occur in warm sector of cyclone which passes N of Mallorca if S'ly gradient is sufficiently strong. Duration * Dependent on speed and trajectory of extra-tropical cyclone and/or associated frontal system. * Not normally long lived.	(1) Anchore la Avan Guarda. (2) Anchore Formento (3) Arriving (4) Small bo

nmental conditions for Pollensa Bay, Mallorca.

VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
(1) Anchored - Between Punta de la Avanzada and Punta de la Guarda.	(a) Wincs blow across anchorage. * Vessels may drag anchor NE toward deeper water. * Two anchors may be required. * Alcudia Bay experiences similar conditions but provides more room for dragging before hazards are encountered.
(2) Anchored - SE of Isla de Formentor.	(a) Winds reach anchorage. * Vessels may drag anchor NE toward/along coast or toward deeper water. * Two anchors may be required. * Alcudia Bay experiences similar conditions but provides more room for dragging before hazards are encountered.

(3) Arriving/departing.	(a) Inbound vessels should be aware of wind effects on anchorages.
	* Winds blow across anchorage between Punta de la Avanzada and Punta de la Guarda.
	  * Vessels may drag anchor NE toward deeper water.
	  * Two anchors may be required.
	  * Wind may generate waves that make small boat operations to/from anchorage and Port of Pollensa hazardous.
	  * Alcudia Bay experiences similar conditions but provides more room for dragging before hazards are encountered.
	* Winds reach anchorage SE of Isla de Formentor.
	  * Vessels may drag anchor NE toward/along coast or toward deeper water.
	  * Two anchors may be required.
	  * Wind may generate waves that make small boat operations to/from anchorage and Port of Pollensa hazardous.
	  * Alcudia Bay experiences similar conditions but provides more room for dragging before hazards are encountered.

(4) Small boats.	(a) Small boat operations may be affected. * Wave height is fetch limited but wind waves may disrupt operations between anchorages and Port of Pollensa. * Because of distance involved, runs to/from anchorage SE of Isla de Formentor would be subject to most disruption.

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL L SITUATION
2. Mistral wind - NW'ly wind that reaches Pollensa Bay across Promontorio del Formentor. * May reach force 5 to 6 (17 to27 kt). * Lack of fetch restricts wave generation. * May be accompanied by sudden squalls in lee of Promontorio del Formentor.	Advance warning * Mistral winds may develop when any of the following occurs: * Formation of a low pressure center in Gulf of Genoa. * Surface front or trough passes Perpignan (07747) or 500 mb trough passes Bordeaux (07510). * When one of the following surface pressure differences is achieved: * Perpignan - Marignane (Marseille), 3 mb, * Marignane - Nice, 3 mb, or * Perignan - Nice, 6 mb. Local Indicator * A red sunset indicates a Mistral will begin in 4-6 hr, and it will be cloudy and windy for next 3 days. Intensity * Strongest winds do not occur until after 500 mb trough has passed. * A good indication of intensity is obtained by adding 10 kt to wind speed reported by Montpelier (07643) or Istres (07647). Duration * Commonly lasts 3-4 days, but a strong Mistral may last as long as 12 days. * Mistral winds will cease/weaken when cyclonic regime at the surface is replaced by anticylonic regime. Associated weather * Rain and violent squalls may accompany the cold front which precedes Mistral. * Squalls can be expected in the lee of high ground, such as Promontorio del Formentor.	(1) Anchored - Be la Avanzada a Guarda. (2) Anchored - SE Formentor. (3) Arriving/depa (4) Small boats.

(Continued)

VESSEL LOCATION/ ITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS

Anchored - Between Punta de la Avanzada and Punta de la Guarda.	(a) Winds blow across anchorage.
	* Vessels may drag anchor SE toward shallow water; two anchors may be required.
	* Vessels are subject to sudden squalls.
	* Alternate ports should be considered.
	  * Alcudia Bay affords better protection from wind and more room for dragging before hazards are encountered.
	  * The Port of Palma feels the wind but it has no effect on the Port.
	  * The Port of Ibiza on the island of Ibiza feels the Mistral about 4 times each year, winter only.
	    * Wind speeds are usually limited to 15-20 kt, rarely reaching 35-40 kt.
	    * Wave heights are limited to 3 ft (about 1 m) or less.
	
	(b) Be aware of wind chill factor.

Anchored - SE of Isla de Formentor.	(a) Wind force is reduced in lee of Isla de Formentor and Promontorio del Formentor, but hazards exist.
	* Strong Mistral may cause vessels to drag anchor; two anchors may be required.
	* Vessels are subject to sudden squalls.
	* Alternate ports should be considered.
	  * Alcudia Bay affords better protection from wind and more room for dragging before hazards are encountered.
	  * The Port of Palma feels the wind but it has no effect on the Port.
	  * The Port of Ibiza on the island of Ibiza feels the Mistral about 4 times each year, winter only.
	    * Wind speeds are usually limited to 15-20 kt, rarely reaching 35-40 kt.
	    * Wave heights are limited to 3 ft (about 1 m) or less.
	
	(b) Be aware of wind chill factor.

Arriving/departing.	(a) Inbound vessels should be aware of wind effects on anchorage.
	* Winds reach both anchorages, but will be reduced in lee of Isla de Formentor.
	* Vessels may drag anchor; two anchors may be required.
	* Small boat operations may be affected.
	  * Wave height is fetch limited, but wind may raise wind waves with potential to disrupt small boat runs between vessels anchored in the E portion of the bay and Port of Pollensa.
	* Vessels in anchorages are subject to sudden squalls.
	* Alternate ports should be considered.
	  * Alcudia Bay affords better protection from wind and more room for dragging before hazards are encountered.
	  * The Port of Palma feels the wind but it has no effect on the Port.
	  * The Port of Ibiza on the island of Ibiza feels the Mistral about 4 times each year, winter only.
	    * Wind speeds are usually limited to 15-20 kt, rarely reaching 35-40 kt.
	    * Wave heights are limited to 3 ft (about 1 m) or less.
	
	(b) Outbound units should not experience any major difficulties.
	* Outbound units should be aware of increased waves from NW which will be encountered when protection of Promontorio del Formentor is lost.
	* Confused sea state is often experienced off of Cabo de Formentor in waters less than 55 fm (100 m) deep.
	* Current with SE set between Mallorca and Menorca increases in speed when Mistral winds are blowing.
	
	(c) Be aware of wind chill factor

Small boats.	(a) Small boat operations may be affected. * Wave height is fetch limited, but wind may raise a sea with the potential to disrupt small boat runs between vessels anchored in the E portion of the Bay and Port of Pollensa. * To minimize effect of wind, small boats should be operated near lee shore whenever possible, but possibility of encountering dangerous sudden squalls in lee of Promontorio del Formentor increases. (b) Be aware of wind chill factor.

For estimating shallow water wave heights, two points have been selected (Figure 2-3). Point 1 is near mid-bay between Punta de la Avanzada and Punta de la Guarda. Point 2 is southwest of Isola de Formentor near the 30 meter depth contour.

Table 2-2 provides the height ratio and direction of shallow water waves to expect at Points 1 and 2 when the deep water wave conditions are known.

The Pollensa Bay Point 1 conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. In the following example, the height is determined by multiplying the deep water height (8 ft) by the ratio of shallow to deep height (.6).

Example: Use of Table 2-2 for Pollensa Bay Point 1.
Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition: 8 feet, 10 seconds, from 090°. The expected wave condition at Pollensa Bay Point 1 as determined from Table 2-2: 5 feet, 10 seconds, from 065°.

NOTE: Wave periods are a conservative property and, therefore, remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of the points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

POLLENSA BAY POINT 1: 75 ft depth

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
030°	040°	040°	040°	045°	050°	055°
	.5	.4	.4	.3	.3	.3
060°	060°	060°	060°	060°	060°	055°
	1.0	.9	.7	.7	.5	.4
090°	080°	075°	065°	070°	070°	065°
	.8	.7	.6	.5	.3	.3
120°	095°	090°	085°	080°	070°	065°
	.8	.7	.6	.4	.5	.1

POLLENSA BAY POINT 2: 100 ft depth

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
030°	045°	045°	045°	045°	050°	055°
	.5	.4	.3	.3	.3	.3
060°	060°	060°	060°	065°	065°	065°
	1.0	.9	.8	.7	.5	.5
090°	090°	085°	085°	080°	080°	075°
	1.0	.9	.7	.5	.6	.4
120°	110°	110°	100°	090°	085°	070°
	.9	.9	.5	.5	.3	.2

The local wind-generated wave conditions for the anchorage area identified as Points 1 and 2 are given in Table 2-3. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing wave height, the time to fetch limited height will be shorter.

Table 2-3. Pollensa Bay. Local wind waves for fetch limited conditions at Points 1 and 2 (based on JONSWAP model).

Points 1 & 2.

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
SE 3 n mi	<2 ft	<2 ft	2/3 1	2/3 1	2-3/3 1
SW 5 n mi	<2 ft	2/3-4 1	2-3/3-4 1	3/3-4 1-2	3-4/3-4 1

> Example:
> To the southwest (225°) of Point 2 there is about a 5 n mi fetch (Figure 2-3). Given a southwest wind at 30 kt, the sea will have reached 2-3 feet with a period of 3-4 seconds within 1 hour. Wind waves will not grow beyond this condition unless the wind speed increases or the direction changes to one over a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-4. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m).

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m) by climatological season.

POLLENSA BAY POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	10	6	2	5
Average Duration (hr)	13	22	11	12
Period Max Energy (sec)	9	8-9	9	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	0	0	0
Average Duration (hr)	15	NA	NA	NA
Period Max Energy (sec)	9-10	NA	NA	NA

POLLENSA BAY POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	15	7	4	9
Average Duration (hr)	13	12	13	12
Period Max Energy (sec)	9	8	8	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	3	1	<< 1	<< 1
Average Duration (hr)	13	6	6	6
Period Max Energy (sec)	10	9	11	9

SEASONAL SUMMARY OF POLLENSA BAY HAZARDOUS WEATHER CONDITIONS

Low, confused (choppy) seas are typically experienced throughout Pollensa Bay in waters less than 100 meters.

WINTER (mid-January thru March):

* Mistral winds: greatest frequency and strength (northwesterly force 5-6 (17-27 kt) late winter-early spring. May be accompanied by sudden squalls in the lee of Promontorio del Formentor.
* SW'ly winds: southerly flow funneled between the peninsulas on either side of the bay. May reach force 5-6 (17-27 kt).
* Easterly winds: called Levante, usually accompanied by cloudy, rainy weather (may last for 3 days).

SPRING (April to mid-June):

* Mistral winds: greatest frequency and strength (northwesterly force 5-6 (17-27 kt) during late winter/early spring. Less frequent after April.
* Levante winds (easterly) possible. Less frequent after April.
* Thunderstorms possible (occurrence frequency: one/month May-October).
* Early morning fog possible (may reduce visibility to about 1 n mi).

SUMMER (mid-June thru September):

* Sea breeze: east to northeasterly, (8-12 kt), near daily occurrence.
* Thunderstorms possible.
* Fog is prevalent in the area during summer.

AUTUMN (October thru mid-January):

* Mistral winds: frequency of occurrence and strength of winds increasing (reaches peak late winter/early spring).
* SW'ly winds: southerly flow funneled between the peninsulas on either side of the bay. May reach force 5-6 (17-27 kt).
* Easterly winds: called Levante, usually accompanied by cloudy, rainy weather (may last for 3 days).

NOTE: For more detailed information on hazardous weather conditions, see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

FICEURLANT, 1987: Port Directory for Pollensa Bay (1982), Balearic Islands. Fleet Intelligence Center Europe and Atlantic, Norfolk, Virginia.

3. GENERAL INFORMATION

This section is intended for Fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of hazards and Table 3-5 provides a summary of vessel locations/situations, potential hazards, effect-precautionary/evasive actions, and advance indicators and other information.

3.1 Geographic Location

Pollensa Bay is located on the island of Mallorca, approximately 100 n mi south-southeast of Barcelona and 165 n mi east of Valencia, Spain (Figure 3-1).

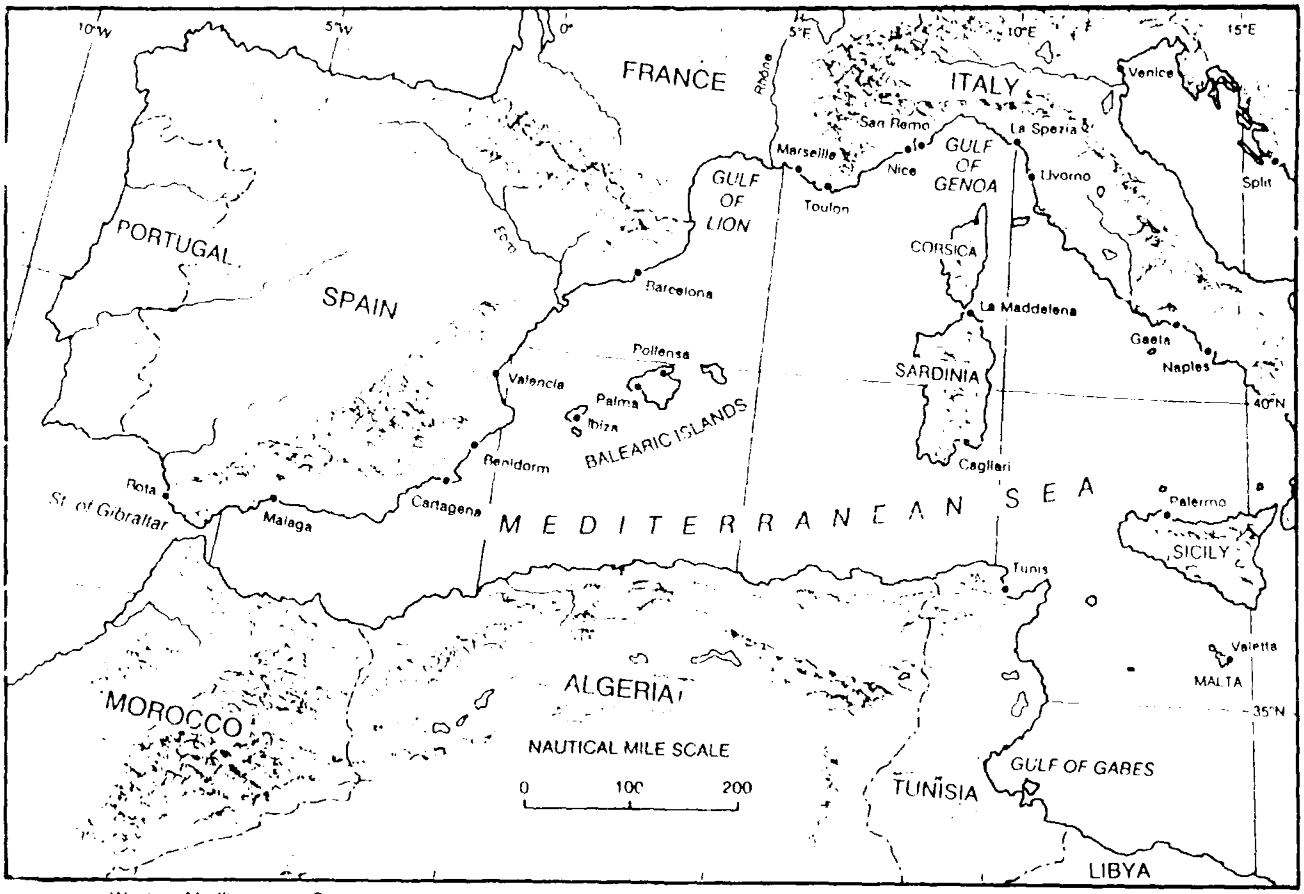

Figure 3-1 Western Mediterranean Sea

Pollensa Bay is situated on the northeast coast of Mallorca just south of Cabo de Formentor, the island's northernmost point (Figure 3-2). With approximate dimensions of 6.5 n mi by 2.75 n mi, the bay lies adjacent to and northwest of the larger Alcudia Bay.

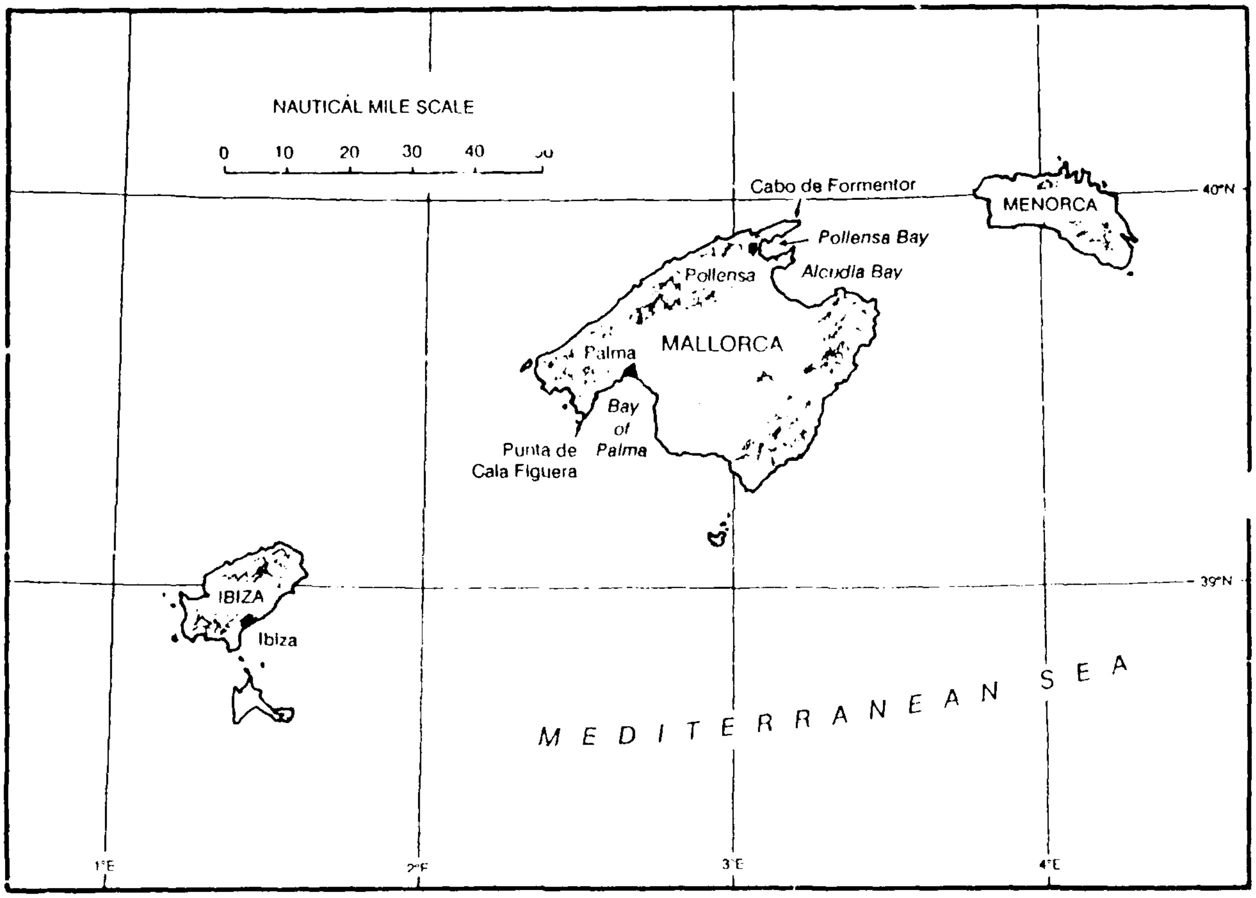

Figure 3 2 Balearic Islands

The Port of Pollensa is situated in the northwest corner of Pollensa Bay, west of Punta de la Avanzada (Figure 3-3). The port is small, with unspecified facilities (FICEURLANT, 1987). Consequently, U.S. Navy ships anchor in the bay instead of mooring at the port. Most vessels anchor between Punta de la Avanzada and Punta de la Guarda, but aircraft carriers anchor southeast of and close to Isla de Formentor in order to gain protection from Promontorio del Formentor.

Pollensa Bay lies between Promontorio del Formentor, on which Cabo de Formentor is located, and an unnamed, shorter, but wider peninsula, which separates Pollensa Bay from Alcudia Bay. Terrain elevations around the bay range from 1,490 ft (454 m) southeast of the bay and 1,089 ft (332 m) west of the bay, to 1,421 ft (433 m) on the northwest. A mountainous ridge extends along the northwest coast of the island and has peaks with maximum heights of 4,741 ft (1,445 m) (FICEURLANT, 1987). East of the ridge and south of Pollensa Bay, lies an island-wide (northeast-southwest) plain. East of the plain is a discontinuous series of low hills.

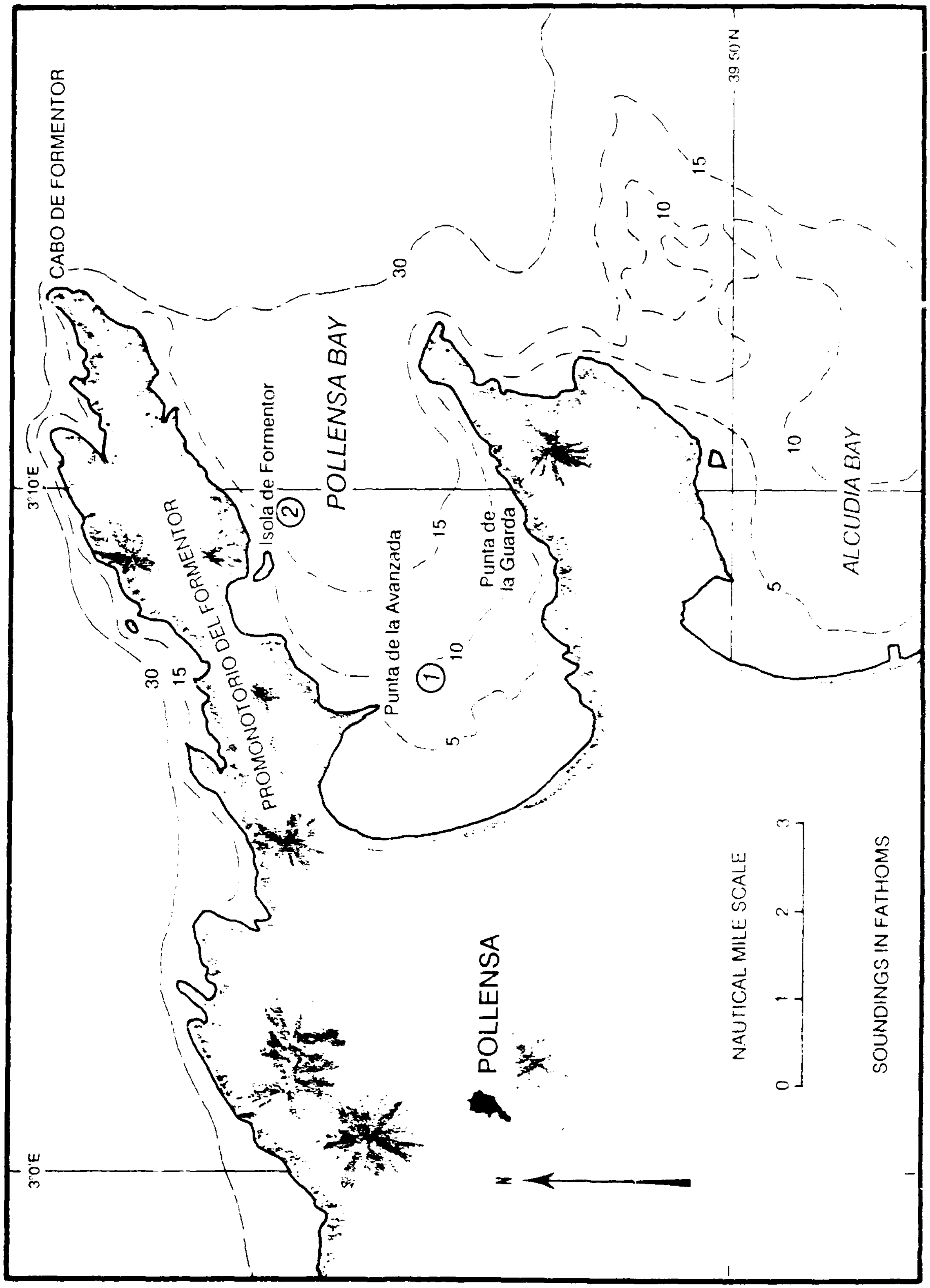

Figure 3-3 Port of Pollensa.

3.2 Qualitative Evaluation of Pollensa Bay as a Haven

Pollensa Bay is bordered by land from the southeast clockwise through the northeast, leaving it exposed to winds and seas from the northeast through the southeast. It is also vulnerable to the strong Mistral winds which originate in the Gulf of Lion (Hydrographic Department, 1963). The bay is also subject to sudden squalls, with the area close to the high terrain on the northwestern side of the bay experiencing the worst conditions. Wave generation due to Mistral winds is limited by the small size of the bay.

Southerly winds funnel to Pollensa Bay as they cross over the island east of the mountainous west coast, reaching the bay as southwesterly force 5 to 6 (17-27 kt).

Holding is considered only fair on a bottom of fine to medium sand, mud, and weed; anchor dragging is a problem in strong winds. Southwesterly winds tend to cause ships to drag anchor northeastward toward deeper water, while the northwesterly Mistral winds cause dragging toward the southeast side of the bay.

3.3 Currents and Tides

Currents within the bay are not specified, but a 1/2 kt current with a southeasterly set flows between Mallorca and Menorca Islands, with the current rate increasing when Mistral winds are blowing.

Astronomical and wind tides are negligible. A barometric pressure tide exists, however, with each 0.4 inches (10 mm) of pressure change resulting in an inverse tidal change of 4 inches (10 cm).

3.4 Visibility

According to local authorities, visibility conditions at Pollensa Bay are generally good, with prevailing visibility usually greater than 7 n mi. Fog occurs on a few days in April, with visibility reduced to about 1 n mi in early morning hours; however, Shaver (undated) states that, according to his experience in the Mediterranean, "... fog is prevalent during the summer months" at Pollensa Bay.

3.5 Hazardous Conditions

The anchorages at Pollensa Bay offer good protection from many weather events, but are exposed and vulnerable to others. A seasonal summary of the various known environmental hazards that may be encountered in Pollensa Bay follows.

A. Winter (mid-January through March)

Mistral winds affect Pollensa Bay about ten percent of the time during the winter season. They usually start as west, but become northwesterly soon after onset, reaching force 5 to 6 (17-27 kt). Wave growth is inhibited within the small confines of the bay, but a strong event can result in anchored vessels dragging anchor. Mistral winds may also cause sudden squalls to occur along the northwest side of the bay in the lee of Promontorio del Formentor. The squalls will pose a particular hazard to small boats.

Strong southerly winds reach the anchorage by crossing the plain which lies east of the mountainous west side of the island, and funneling between the two peninsulas on either side of the bay. They reach the anchorages as southwesterly force 5 to 6 (17-27 kt), and may cause vessels to drag anchor northeastward toward deeper water. The winds are most likely caused by a prefrontal Vendaval situation occurring in advance of a cold front as it crosses the Iberian Peninsula. But they

may also result from a particularly strong Scirocco (Xaloc) event as warm air is drawn northward in the warm sector of a depression passing north of Mallorca.

Easterly winds do not pose a significant hazard to ships at Pollensa Bay, but the orientation of the bay will allow westerly moving waves to refract southwestward to the anchorages. Easterly winds, called Levante, are usually accompanied by cloudy, rainy weather which may last for approximately three days.

While specific precipitation data for Pollensa Bay are unavailable, Biel (1946) states the probability of days with precipitation in the Balearic Islands to be 31 percent in January, decreasing to 20 percent in April. Using these figures as a guide, and comparing them with rainfall records for Palma, Mallorca (located about 30 n mi southwest of Pollensa Bay), it is reasonable to expect precipitation on about 8 or 9 days in January, 7 or 8 days in February, and 7 or 8 days in March. Thunderstorms are not common during winter.

Temperatures are moderate during winter, with freezing temperatures rare. Records for Palma, Mallorca, indicate that during January and February, the coldest months, the mean daily maximum temperature is near 57°F (14°C), while the mean minimum is 44°F (7°C). While wind chill is not normally a problem on Mallorca, a strong, cold Mistral outbreak may be cause for concern for personnel working in exposed locations. Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
Calm	Calm	40	35	30	25	20	15	10	5	0
		Equivalent Chill Temperature								
3-6	5	35	30	25	20	15	10	5	0	-5
7-10	10	30	20	15	10	5	0	-10	-15	-20
11-15	15	25	15	10	0	-5	-10	-20	-25	-30
16-19	20	20	10	5	0	-10	-15	-25	-30	-35
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55

B. Spring (April to mid-June)

Mistral winds over the Gulf of Lion occur with greatest frequency and strength in late winter and early spring. At Pollensa Bay, Mistral winds continue with about a ten percent frequency of occurrence through April, after which they become less frequent and weaker.

Southerly winds still funnel across Pollensa Bay, but become less frequent after April as the incidence of extratropical cyclones and associated cold frontal activity decreases.

Easterly Levante winds, with associated clouds and rain, regularly occur through April, after which they also become less frequent.

Precipitation amounts remain essentially constant from January through May, but the number of days that record 0.04 inches or more of rain decreases, indicating shorter periods of heavier, showery type precipitation. In June, rain amount decreases to half that of May. Thunderstorm activity, while never frequent, becomes more common starting in May. A frequency of occurrence of about 1 per month is normal from May to October.

Early morning fog normally reduces visibility to about 1 n mi in the morning hours during a few days in April, but visibility is usually greater than 7 n mi.

As would be expected, temperatures warm significantly during the season. By June, the mean daily maximum temperature is near 78°F (26°C), and the mean daily minimum is about 64°F (18°C).

C. Summer (mid-June through September)

The summer season on Mallorca is pleasant, with generally light winds and warm temperatures prevailing. Mistral events are possible, but occurrences are infrequent and weak. A consistent east to northeasterly sea breeze occurs daily with a wind speed commonly less than force 4 (11-16 kt). Precipitation is at its yearly minimum during July, but increases dramatically in September. Thunderstorms occur at a rate of about 1 per month.

Although discussions with local authorities gave no indication of fog occurrence during summer, Shaver (undated) specifically mentions that fog is prevalent during the summer months.

D. Autumn (October to mid-January)

The Autumn season sees a return to cooler temperatures, stronger winds, and more frequent periods of inclement weather. Mistral winds occur more frequently and are stronger than during the summer months, but do not reach their peak activity until late winter/early spring.

Southerly wind events occur with increasing frequency as extratropical cyclone activity increases in concert with a return of the storm track to the Mediterranean basin. Vendaval winds preceding cold frontal passages funnel to Pollensa Bay between its bordering peninsulas.

The increase in extratropical cyclone activity also brings an increase in easterly Levante winds and associated clouds and rain. October precipitation is the highest of the year, after which the monthly amounts decrease through the remainder of the season.

3.6 Harbor Protection

As discussed below, the anchorages at Pollensa Bay are well protected from most wave conditions but are vulnerable to winds.

3.6.1 Wind and Weather

Although the commonly used anchorages between Punta de la Avanzada and Punta de la Guarda, and off Isla de Formentor, are relatively close to Promontorio del Formentor, Mistral winds reach them. The northwesterly winds reach force 5 to 6 (17-27 kt), and may cause vessels to drag anchor due to the lack of sufficient holding quality of the bottom. A second anchor may be required to preclude dragging southeastward toward the peninsula that separates Pollensa Bay from Alcudia Bay. Mistral winds may be accompanied by sudden squalls along the northwest side of the bay in the lee of Promontorio del Formentor, and endanger small boats.

A similar anchor dragging problem exists whenever synoptic scale southerly flow crosses the island. Speeds can reach force 5 to 6 (17-27 kt), causing vessels to drag anchor northeastward toward deeper water. A second anchor may be required.

An instance is cited in the Port Directory (FICEURLANT, 1987), that says a destroyer experienced holding difficulties and dragged a 4,000 pound patent Navy stockless anchor. A 2,135 pound Danforth anchor used with 90 fm (164 m) of chain subsequently held.

3.6.2 Waves

During discussions with local authorities about hazardous conditions that affect Pollensa Bay, waves were not identified as a problem. Waves generated by easterly

winds undoubtedly reach the anchorages but apparently cause no difficulties.

Confused seas of unspecified height often exist off Cabo de Formentor and in the mouth of Pollensa Bay in waters less than 55 fm (100 m) deep.

Table 3-2 provides the shallow water wave conditions at the two designated points when deep water swell enters the harbor.

Example: Use of Table 3-2.

For a deep water wave condition of:

8 feet, 10 seconds, from 090°

The approximate shallow water wave conditions are:

Point 1: 5 feet, 10 seconds, from 065°
Point 2: 5-6 feet, 10 seconds, from 085°

Table 3-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of the points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

POLLENSA BAY POINT 1:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
030°	040°	040°	040°	045°	050°	055°
	.5	.4	.4	.3	.3	.3
060°	060°	060°	060°	060°	060°	055°
	1.0	.9	.7	.7	.5	.4
090°	080°	075°	065°	070°	070°	065°
	.8	.7	.6	.5	.3	.3
120°	095°	090°	085°	080°	070°	065°
	.8	.7	.6	.4	.5	.1

POLLENSA BAY POINT 2:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
030°	045°	045°	045°	045°	050°	055°
	.5	.4	.3	.3	.3	.3
060°	060°	060°	060°	065°	065°	065°
	1.0	.9	.8	.7	.5	.5
090°	090°	085°	085°	080°	080°	075°
	1.0	.9	.7	.5	.6	.4
120°	110°	110°	100°	090°	085°	070°
	.9	.9	.5	.5	.3	.2

Situation-specific shallow water wave conditions resulting from deep water wave propagation are given in Table 3-2 while the seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-3. If the actual or forecast deep water wave conditions are known, the expected conditions at the two specified harbor areas can be determined from Table 3-2. The mean duration of the condition, based on the shallow water wave heights, can be obtained from Table 3-3.

Example: Use of Tables 3-2 and 3-3.

The forecast for wave conditions tomorrow (winter case) outside the harbor are:

8 feet, 10 seconds, from 120°

Expected shallow water conditions and duration:

	Point 1	Point 2
height	5 feet	4 feet
period	10 seconds	10 seconds
direction	from 085°	from 100°
duration	13 hours	13 hours

Interpretation of the information from Tables 3-2 and 3-3 provides guidance on the local wave conditions expected tomorrow at the various harbor points. The duration values are mean values for the specified height range and season. Knowledge of the current synoptic pattern and forecast/expected duration should be used when available.

Possible applications to small boat operations are selection of the mother ships anchorage point and/or areas of small boat work. The condition duration information provides insight as to how long before a change can be expected. The local wave direction information can be of use i. selecting anchorage configuration and related small boat operations, including tending activities.

Table 3-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m) by climatological season.

POLLENSA BAY POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	10	6	2	5
Average Duration (hr)	13	22	11	12
Period Max Energy(sec)	9	8-9	9	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	0	0	0
Average Duration (hr)	15	NA	NA	NA
Period Max Energy(sec)	9-10	NA	NA	NA
POLLENSA BAY POINT 2:	**WINTER**	**SPRING**	**SUMMER**	**AUTUMN**
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	15	7	4	9
Average Duration (hr)	13	12	13	12
Period Max Energy(sec)	9	8	8	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	3	1	<< 1	<< 1
Average Duration (hr)	13	6	6	6
Period Max Energy(sec)	10	9	11	9

Local wind wave conditions are provided in Table 3-4 for Pollensa Bay Points 1 and 2. The fetch lengths are specifically for Points 1 and 2. The time to reach the fetch limited height assumes an initial flat ocean. With a pre-existing wave height, the times are shorter.

Table 3-4. Pollensa Bay. Local wind waves for fetch limited conditions at Points 1 and 2 (based on JONSWAP model).

Points 1 and 2.

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and\ Fetch \ Length \ (n mi)	Local Wind Speed (kt) 18	24	30	36	42
SE 3 n mi	<2 ft	<2 ft	2/3 1	2/3 1	2-3/3 1
SW 5 n mi	<2 ft	2/3-4 1	2-3/3-4 1	3/3-4 1-2	3-4/3-4 1

Example: Small boat wave forecasts for Points 1 & 2 (based on the assumption that swell is not a limiting condition).

Forecast for Tomorrow:

Time	Wind (Forecast)	Waves (Table 3-4)
prior to 0800 LST	light and variable	< 2 ft
0800 to 1300	SW 16-20 kt	< 2 ft
1300 to 1800	SW 28-32 kt	building to 2-3ft at 3-4 sec by 1300
1800 to 2100	SW decreasing to less than 12 kt	< 2 ft

Interpretation: Assuming that the limiting factor is waves greater than 3 feet, small boat operations will become marginal by 1300 and remains so until after 1800.

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell heights. For example, if the wind waves were 3 ft and the swell 8 ft the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height the combined heights are only 1.4 times the equal height. In cases where one or the other heights are twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height).

3.6.3 Wave Data Uses and Considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period and, therefore, length of wind waves is generally short relative to the period and length of waves propagated into the harbor (see Appendix A). The shorter period and length result in wind waves characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave train heights are not significantly high. Vessels of various lengths may respond with different motions to the diverse wave lengths present. The information on wave periods, provided in the previous tables, should be considered when forecasts are made for joint operations of various length vessels.

3.7 Protective/Mitigating Measures

As discussed in Section 3.6, vessels in the anchorage are subject to anchor dragging in strong wind situations. Deployment of a second anchor may be sufficient to solve the problem, but in the relatively narrow confines of the bay it may be advisable to move to a safer anchorage. The anchorage at the adjacent Alcudia Bay has an exposure similar to Pollensa Bay's, but the larger size of the bay provides more room to move before hazards are encountered. If Mistral winds are the

problem, Alcudia Bay affords better protection than Pollensa Bay (Hydrographic Department, 1963). The Port of Palma on the southwest side of Mallorca also would afford better protection from Mistral conditions. The winds reach the port but have no effect on port operations. The Port of Ibiza on the island of Ibiza is also a viable alternate port. The port is affected somewhat by Mistral winds, but they usually are in the 15-20 kt range and occur only about 4 times per year, winter only. They only rarely attain 30-40 kt speeds. Because of the refraction around the island that the waves must undergo before reaching the port, wave heights from Mistral winds at Ibiza are limited to 3 ft (about 1 m) or less.

3.8 Indicators of Hazardous Weather Conditions

Two weather events, northwesterly Mistral winds and southerly winds which cross the island and reach Pollensa Bay from the southwest, cause the greatest problem for ships anchored in Pollensa Bay---anchor dragging. Because of the potential hazards that could result, it is advisable to be aware of forthcoming weather events which could cause a problem. The following guidelines are intended to provide the insight necessary to enable the meteorologist to anticipate the onset, duration, and intensity of hazardous weather conditions.

3.8.1 Mistral

Mistral winds reach the anchorage as northwesterly force 5 to 6 (17-27 kt). They may be accompanied by sudden squalls along the lee of the peninsula northwest of the bay, Promontorio del Formentor. The following is an abbreviated list of

Mistral guidelines adapted from Brody and Nestor (1980). For a more complete listing, refer to the NEPRF Severe Weather Guides for Marseille or Toulon, France.

1. <u>Causes</u>

The Mistral is the result of a combination of the following factors:

(a) The basic circulation that creates a pressure gradient from west to east along the coast of southern France. This pressure gradient is normally associated with Genoa cyclogenesis.

(b) A fall wind effect caused by cold air associated with the Mistral moving downslope as it approaches the southern coast of France and thus increasing the wind speed.

(c) A jet effect wind increase caused by the orographic configuration of the coastline. This phenomenon is observed at the entrance to major mountain gaps such as the Carcassone Gap, Rhône Valley, and Durance Valley.

(d) A wind increase over the open water resulting from the reduction in the braking effect of surface friction (as compared to the braking effect over land).

2. <u>Onset</u>

(a) A Mistral generally sets in when a surface front or trough passes Perpignan (07747), or the 500 mb trough passes Bordeaux (07510). (Note: These two events are expected to occur nearly simultaneously.)

(b) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of Genoa lows.

(c) If a 500 mb trough extends from central Europe southward over North Africa, a surface low from Algeria may propagate northward, intensify in the Gulf of Genoa, and initiate a Mistral.

(d) If a 500 mb cut-off low forms over northeast France and produces a northwesterly flow at 500 mb over the south coast, a Mistral may occur even

though 500 mb wind speeds do not reach 50 kt and the jet axis is located far to the west and south.

(e) The Mistral will start when any one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice, 6 mb. A difference usually occurs within 24 hours after a closed Genoa low appears, but it occasionally occurs earlier.

(f) Wave clouds, such as observed on high-resolution Defense Meteorological Satellite Program (DMSP) satellite imagery, are observed over the Massif Central of southern France approximately 6 hours before the start of a Mistral.

(g) Lus La Croix Haute (07587) will provide a 2-3 hour advance notice of Mistral onset. The wind speed will closely approximate the wind speed in the Gulf. (Note: Usefulness of this station is limited because it only reports every 3 hours.)

(h) Orange (07579) gives a 3-4 hour warning of a gale force Mistral when winds at this station increase to northwesterly 25 kt. Hourly reports are available.

(i) It is possible to forecast the onset of a Mistral in the Gulf of Lion by observing changes in the normally strong afternoon sea breeze (east-southeasterly) direction at Perpignan. If the wind shifts to northerly with speeds increasing to 25-30 kt, and the temperature drops at least 3°F, a strong Mistral (40-50 kt) will be blowing in the Gulf of Lion within 6 hours.

3. Intensity

(a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. This usually occurs well after the surface cold frontal passage.

(b) Satellite observations indicating a strong Mistral will exhibit the following features: cloudy over France and clear over the water area south of the 1,000 ft water depth contour; clear over the Gulf of

Lion except for a cloud mass parallel to the coast, lying 75-150 n mi offshore; and/or wispy cloud streaks extending from 315° to 360° into offshore clouds.

(c) Wave clouds extending from Sardinia to Tunisia, viewed on satellite imagery, are generally associated with gale force Mistral situations.

(d) Maximum Mistral winds occur when the surface isobars are at an angle of 30° to the valleys of either the Garonne, the Rhône, or the Durance with low pressure to the southeast.

(e) The information below can be used to estimate wind speed associated with a Mistral in the Gulf of Lion.

Pressure Difference (mb)	Perpignan* (station 07747) and Nice (station 07690)	Perpignan* and Marignane (station 07650)	Marignane** and Nice
3		30-35 kt	30-35 kt
4		40	40
5		45-50	45-50
6	30-35 kt		
8	40		
10	45-50		

* Highest pressure at Perpignan
** Highest pressure at Marignane

(f) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647).

(g) If the 500 mb winds reported at either Bordeaux (07510) or Brest (07110) are north-westerly at 65 kt or greater, storm force winds are indicated for the Gulf of Lion.

(h) Wind speeds over open water during a Mistral will be approximately double those measured at Perpignan or Marignane (Marseille) except in storm conditions, when the ratio will be lower.

4. <u>Duration</u>

(a) A strong Mistral may last for as many as 12 days without any important lulls. The most frequent length of an occurrence is about 3 1/2 days (Meteorological Office, Air Ministry, 1962).

(b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. Indications of this change include:

(1) The 500 mb ridge beginning to move over the Mistral area.

(2) High pressure at the surface begins to move into the western basin of the Mediterranean.

(3) There is a change that reduces the pressure difference between France and the western basin.

5. <u>Associated Weather</u>

Rain and violent squalls commonly accompany the cold front which precedes the Mistral. Where there is high ground, such as that northwest of Pollensa Bay, sudden squalls can be expected in the lee during strong northwesterly winds.

6. <u>Local Indicators</u>

Local authorities state that a red sunset indicates a Mistral will begin in 4 to 6 hours, and it will be cloudy and windy for the next 3 days. The wind usually begins with a westerly direction. This guideline is claimed to be 95 percent accurate by local users.

3.3.2 <u>Southwesterly winds</u>

Synoptic scale southerly flow across Mallorca may result in wind which reaches Pollensa Bay as southwesterly force 5 to 6 (17-27 kt). Southerly flow may be caused by either of two primary situations.

1. A prefrontal gradient wind known as Vendaval has the potential to cause the strongest southwesterly wind at Pollensa Bay. Wind force would gradually

increase with the approach of a cold front, and subside after frontal passage, as the wind direction veers.

2. A Scirocco event, known locally as Xaloc, may be strong enough to funnel gusty winds to Pollensa Bay. Such occurrences would likely be less strong than Vendaval winds, and would be experienced in the warm sectors of cyclones located north of Mallorca.

3.9 Summary of Problems, Actions, and Indicators

Table 3-5 is intended to provide easy-to-use seasonal references for meteorologists on ships using the anchorage at Pollensa Bay. Table 2-1 (section 2) summarizes Table 3-5 and is intended primarily for use by ship captains.

Table 3-5. Potential problem situation

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTI
1. Anchored - Between Punta de la Avanzada and Punta de la Guarda. Occurs in Winter & Spring *Least likely in Summer* Also occurs in Autumn	a. SW'ly wind - Results when S'ly flow crosses the plain E of the mountainous W coast of Mallorca and funnels between the peninsulas that form the NW and SE sides of the bay. Often reaches force 5 to 6 (17 to 27 kt), but wave generation is limited by lack of fetch. May be caused by SW'ly winds ahead of an approaching cold front or strong S'ly flow in warm sector of depression passing N of Mallorca. May be accompanied by low clouds and/or precipitation.	a. Wind force and only fair holding g drag anchor NE toward deeper water. A adjacent Alcudia Bay is subject to sim affords more dragging room before haza
Strongest in Winter & early Spring Weakest in Summer Occurs in Autumn	b. Mistral wind - NW'ly wind that reaches Pollensa Bay as force 5 to 6 (17 to 27 kt). Lack of fetch limits wave generation. May be accompanied by sudden squalls in the lee of Promontorio del Formentor.	b. Wind force and only fair holding g to drag anchor SE toward shallow water adjacent Alcudia Bay affords better pr dragging room before hazards are encou of Mallorca would afford good protecti on the island of Ibiza should also be about 4 times per year (winter only), They only rarely reach 35-40 kt. Wave are limited to 3 ft (about 1 m) or les

uations at Pollensa Bay, Mallorca - ALL SEASONS

ECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
holding quality of the bottom may cause vessels to r water. A second anchor may be required. The ect to similar conditions, but its larger size before hazards are encountered.	a. The most probable cause of strong SW'ly winds at Pollensa Bay is a synoptic scale event, such as the SW'ly Vendaval winds that precede cold fronts which move E across the Iberian Peninsula, or the SE'ly Scirocco (Xaloc) winds occurring in the warm sector of cyclones passing N of Mallorca. Since each event is transitory, the SW'ly wind should not be long lasting.
holding qualities of the bottom may cause vessels low water. A second anchor may be required. The s better protection and its larger size affords more s are encountered. The Port of Palma on the SW side ood protection and better holding. The Port of Ibiza ld also be considered. It experiences Mistral winds ter only, but they are usually limited to 15-20 kt. kt. Wave heights at Ibiza due to Mistral winds m or less. Be aware of wind chill factor.	b. The following is an abbreviated listing of the many guidelines available that aid in forecasting the onset, intensity, and duration of Mistral events. Refer to section 3.8.1 of the accompanying text for a more complete listing. (1) Causes. Mistral winds result from a combination of several factors, including: (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. (c) A jet effect resulting from air moving through gaps and valleys in mountains near the coast. (d) A wind increase over open water due to a lessening of surface friction. (2) Onset. (a) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of low pressure centers in the Gulf of Genoa. (b) A Mistral generally sets in when a surface front or trough passes Perpignan (07747) or the 500 mb trough passes Bordeaux (07510). (c) The Mistral will start when one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 7 mb; or Perpignan - Nice, 6 mb. A difference usually occurs within 24 hr after a closed Genoa Low appears, but it occasionally occurs sooner. (3) Intensity. (a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. (b) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647). (4) Duration. (a) The most frequent length of a Mistral is 3.5 days, but a strong Mistral may last for 12 days. (b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. (5) Associated weather. Rain and violent squalls commonly accompany the cold front which precedes the Mistral. Where there is high ground, such as that NW of Pollensa Bay, sudden squalls can be expected in the lee. (6) Local indicator. Local authorities state that a red sunset indicates a Mistral will begin in 4 to 6 hr, and it will be cloudy and windy for the next 3 days.

Table 3-5.

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUT
2. Anchored - SE of Isla de Formentor. Occurs in Winter & Spring Least likely in Summer Also occurs in Autumn	a. SW'ly wind - Results when S'ly flow crosses the plain E of the mountainous W coast of Mallorca and funnels between the peninsulas that form the NW and SE sides of the bay. Often reaches force 5 to 6 (17 to 27 kt), but wave generation is limited by lack of fetch. May be caused by SW'ly winds ahead of an approaching cold front or strong S'ly flow in warm sector of depression passing N of Mallorca. May be accompanied by low clouds and/or precipitation.	a. Wind force and only fair holding c drag anchor NE toward deeper water. A adjacent Alcudia Bay is subject to si affords more dragging room before haza
Strongest in Winter & early Spring Weakest in Summer Occurs in Autumn	b. Mistral wind - NW'ly wind that reaches Pollensa Bay as force 5 to 6 (17 to 27 kt). Lack of fetch limits wave generation. May be accompanied by sudden squalls in the lee of Promontorio del Formentor.	b. Wind force in the lee of Promontor would be less than that experienced a high ground, but in a strong Mistral drag anchor SE. A second anchor may b anchorage is desired, the adjacent Alc protection, and more room to drag befo Palma on the SW side of Mallorca would holding. The Port of Ibiza on the isl It experiences Mistral winds about 4 usually limited to 15-20 kt. They onl Ibiza due to Mistral winds are limite wind chill factor.

ble 3-5. (Continued)

PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
fair holding quality of the bottom may cause vessels to eeper water. A second anchor may be required. The subject to similar conditions, but its larger size me before hazards are encountered.	a. The most probable cause of strong SW'ly winds at Pollensa Bay is a synoptic scale event, such as the SW'ly Vendaval winds that precede cold fronts which move E across the Iberian Peninsula, or the SE'ly Scirocco (Xaloc) winds occurring in the warm sector of cyclones passing N of Mallorca. Since each event is transitory, the SW'ly wind should not be long lasting.
e of Promontorio del Formentor and Isla de Formentor experienced away from the protection of the relatively rong Mistral may still be sufficient to cause ships to d anchor may be required. If moving to a more sheltered e adjacent Alcudia Bay provides somewhat better e to drag before hazards are encountered. The Port of Mallorca would afford good protection, and better iza on the island of Ibiza should also be considered. winds about 4 times per year (winter only), but they are kt. They only rarely reach 35-40 kt. Wave heights at nds are limited to 3 ft (about 1 m) or less. Be aware of	b. The following is an abbreviated listing of the many guidelines available that aid in forecasting the onset, intensity, and duration of Mistral events. Refer to section 3.8.1 of the accompanying text for a more complete listing. (1) <u>Causes</u>. Mistral winds result from a combination of several factors, including: (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. (c) A jet effect resulting from air moving through gaps and valleys in mountains near the coast. (d) A wind increase over open water due to a lessening of surface friction. (2) <u>Onset</u>. (a) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of low pressure centers in the Gulf of Genoa. (b) A Mistral generally sets in when a surface front or trough passes Perpignan (07747) or the 500 mb trough passes Bordeaux (07510). (c) The Mistral will start when one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice, 6 mb. A difference usually occurs within 24 hr after a closed Genoa Low appears, but it occasionally occurs sooner. (3) <u>Intensity</u>. (a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. (b) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647). (4) <u>Duration</u>. (a) The most frequent length of a Mistral is 3.5 days, but a strong Mistral may last for 12 days. (b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. (5) <u>Associated weather</u>. Rain and violent squalls commonly accompany the cold front which precedes the Mistral. Where there is high ground, such as that NW of Pollensa Bay, sudden squalls can be expected in the lee. (6) <u>Local indicator</u>. Local authorities state that a red sunset indicates a Mistral will begin in 4 to 6 hr, and it will be cloudy and windy for the next 3 days.

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECA
3. Arriving/departing. Occurs in Winter & Spring Least likely in Summer Also occurs in Autumn	a. SW'ly wind - Results when S'ly flow crosses the plain E of the mountainous W coast of Mallorca and funnels between the peninsulas that form the NW and SE sides of the bay. Often reaches force 5 to 6 (17 to 27 kt), but wave generation is limited by lack of fetch. May be caused by SW'ly winds ahead of an approaching cold front or strong S'ly flow in warm sector of depression passing N of Mallorca. May be accompanied by low clouds and/or precipitation.	a. Inbound vessels should be aw bottom quality, and be prepared in the adjacent Alcudia Bay woul encountered. Outbound vessels s anchorage but may encounter 10 t Mallorca. Confused sea state is waters less than 55 fm (100 m) d
Strongest in Winter & early Spring Weakest in Summer Occurs in Autumn	b. Mistral wind - NW'ly wind that reaches Pollensa Bay as force 5 to 6 (17 to 27 kt). Lack of fetch limits wave generation. May be accompanied by sudden squalls in the lee of Promontorio del Formentor.	b. Inbound vessels should be aw bottom quality, and be prepared close to the high ground on the somewhat, but expose the ship to squalls which occur in the lee o limited because of a short fetch potential to disrupt small boat Pollensa. All anchorages are vu Formentor would likely be higher Alcudia Bay provides better prot Port of Palma on the SW side of holding. The Port of Ibiza on the experiences Mistral winds about usually limited to 15-20 kt, rar to Mistral winds are limited to Pollensa Bay is limited because with the potential to disrupt sm the Port of Pollensa. Outbound u which will be encountered when pr Confused sea state is often exper than 55 fm (100 m) deep. Current increases in speed when Mistral

(C ble 3-5. (Continued)

ONARY	PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
holding loy 2 an rd more experien t (3 to observ	d be aware of holding problems caused by wind force and epared to deploy 2 anchors if required. The anchorage Bay would afford more room to drag before hazards are ssels should experience no difficulty leaving the er 10 to 13 ft (3 to 4 m) waves when out of the lee of tate is often observed off of Cabo de Formentor in m) deep.	a. The most probable cause of strong SW'ly winds at Pollensa Bay is a synoptic scale event, such as the SW'ly Vendaval winds that precede cold fronts which move E across the Iberian Peninsula, or the SE'ly Scirocco (Xaloc) winds occurring in the warm sector of cyclones passing N of Mallorca. Since each event is transitory, the SW'ly wind should not be long lasting.
holding loy 2 an le of the her prob ontorio the wind ions bet le, but to the in from th ca would and of Ib es per ye eaching 3 (about 1 short fet at opera should be ion of Pr ed off of SE set b are blow	d be aware of holding problems caused by wind force and epared to deploy 2 anchors if required. Anchoring on the NW side of the bay would reduce wind force ship to a higher probability of experiencing the sudden e lee of Promontorio del Formentor. Wave generation is s fetch, but the wind may raise a sea with the l boat operations between the anchorages and the Port of are vulnerable, but waves at the anchorage SE of Isla de higher due to the increased fetch length. The adjacent er protection from the wind, and more dragging room. The de of Mallorca would afford good protection and better a on the island of Ibiza should also be considered. It about 4 times per year (winter only), but they are t, rarely reaching 35-40 kt. Wave heights at Ibiza due ted to 3 ft (about 1 m) or less. Wave generation at ecause of a short fetch, but the wind may raise a sea rupt small boat operations between the anchorages and bound units should be aware of increased waves from NW when protection of Promontorio del Formentor is lost. en experienced off of Cabo de Formentor in waters less urrent with SE set between Mallorca and Menorca istral winds are blowing. Be aware of wind chill factor.	b. The following is an abbreviated listing of the many guidelines available that aid in forecasting the onset, intensity, and duration of Mistral events. Refer to section 3.8.1 of the accompanying text for a more complete listing. (1) Causes. Mistral winds result from a combination of several factors, including: (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. (c) A jet effect resulting from air moving through gaps and valleys in mountains near the coast. (d) A wind increase over open water due to a lessening of surface friction. (2) Onset. (a) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of low pressure centers in the Gulf of Genoa. (b) A Mistral generally sets in when a surface front or trough passes Perpignan (07747) or the 500 mb trough passes Bordeaux (07510). (c) The Mistral will start when one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice, 6 mb. A difference usually occurs within 24 hr after a closed Genoa Low appears, but it occasionally occurs sooner. (3) Intensity. (a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. (b) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647). (4) Duration. (a) The most frequent length of a Mistral is 3.5 days, but a strong Mistral may last for 12 days. (b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. (5) Associated weather. Rain and violent squalls commonly accompany the cold front which precedes the Mistral. Where there is high ground, such as that NW of Pollensa Bay, sudden squalls can be expected in the lee. (6) Local indicator. Local authorities state that a red sunset indicates a Mistral will begin in 4 to 6 hr, and it will be cloudy and windy for the next 3 days.

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAL
4. Small boats. Occurs in Winter & Spring Least likely in Summer Also occurs in Autumn	a. SW'ly wind - Results when S'ly flow crosses the plain E of the mountainous W coast of Mallorca and funnels between the peninsulas that form the NW and SE sides of the bay. Often reaches force 5 to 6 (17 to 27 kt), but wave generation is limited by lack of fetch. May be caused by SW'ly winds ahead of an approaching cold front or strong S'ly flow in warm sector of depression passing N of Mallorca. May be accompanied by low clouds and/or precipitation.	a. Wave generation is limited be wind waves with the potential to the Port of Pollensa. All anchor SE of Isla de Formentor would lik length.
Strongest in Winter & early Spring Weakest in Summer Occurs in Autumn	b. Mistral wind - NW'ly wind that reaches Pollensa Bay as force 5 to 6 (17 to 27 kt). Lack of fetch limits wave generation. May be accompanied by sudden squalls in the lee of Promontorio del Formentor.	b. Wave generation is limited be wind waves with the potential to anchored in the E portion of the difficulties with waves if operat such operations expose the boats dangerous squalls which occur nea chill factor.

Table 3-5. (Continued)

CAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
...ed because of a short fetch, but the wind may raise ... to disrupt operations between the anchorages and ...anchorages are vulnerable, but waves at the anchorage ... likely be higher due to the increased fetch	a. The most probable cause of strong SW'ly winds at Pollensa Bay is a synoptic scale event, such as the SW'ly Vendaval winds that precede cold fronts which move E across the Iberian Peninsula, or the SE'ly Scirocco (Xaloc) winds occurring in the warm sector of cyclones passing N of Mallorca. Since each event is transitory, the SW'ly wind should not be long lasting.
...ed because of a short fetch, but the wind may raise ... to disrupt small boat operations to/from vessels ... the Bay. Boats should experience minimal ...operated as near the lee shore as possible. However, ...boats to a greater probability of encountering sudden ... near Promontorio del Formentor. Be aware of wind	b. The following is an abbreviated listing of the many guidelines available that aid in forecasting the onset, intensity, and duration of Mistral events. Refer to section 3.8.1 of the accompanying text for a more complete listing. (1) Causes. Mistral winds result from a combination of several factors, including: (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. (c) A jet effect resulting from air moving through gaps and valleys in mountains near the coast. (d) A wind increase over open water due to a lessening of surface friction. (2) Onset. (a) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of low pressure centers in the Gulf of Genoa. (b) A Mistral generally sets in when a surface front or trough passes Perpignan (07747) or the 500 mb trough passes Bordeaux (07510). (c) The Mistral will start when one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice, 6 mb. A difference usually occurs within 24 hr after a closed Genoa Low appears, but it occasionally occurs sooner. (3) Intensity. (a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. (b) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647). (4) Duration. (a) The most frequent length of a Mistral is 3.5 days, but a strong Mistral may last for 12 days. (b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. (5) Associated weather. Rain and violent squalls commonly accompany the cold front which precedes the Mistral. Where there is high ground, such as (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. that NW of Pollensa Bay, sudden squalls can be expected in the lee. (6) Local indicator. Local authorities state that a red sunset indicates a Mistral will begin in 4 to 6 hr, and it will be cloudy and windy for the next 3 days.

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PORT VISIT INFORMATION

MAY 1987. NEPRF meteorologists D. Perryman and R. Miller met with the Chief Pilot to obtain much of the information used in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always

present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining

frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing

lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)	Sig Wave (H1/3) Period/Height (sec) (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water

conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

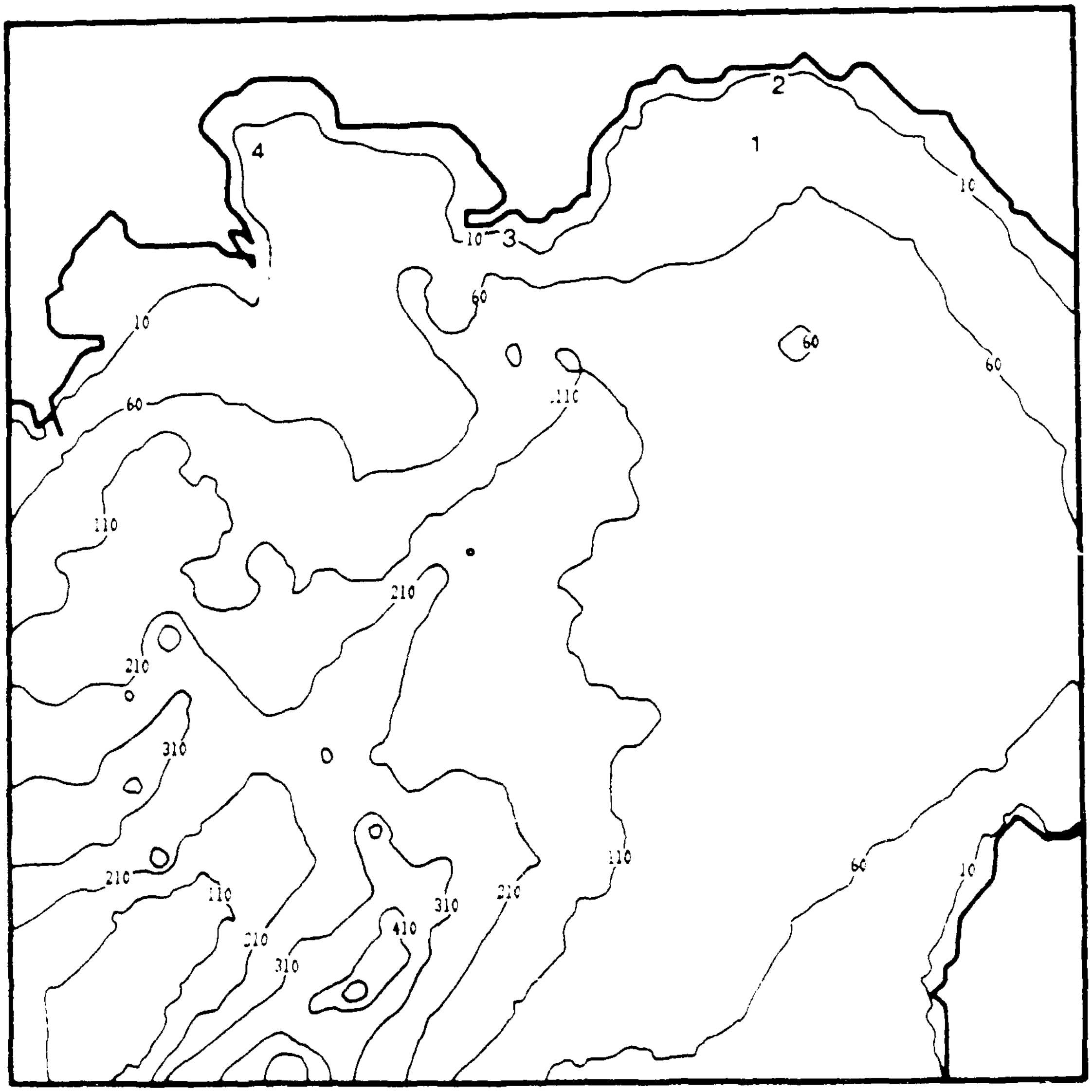

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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